Last Time…

What other factors (non-human) influence climate?

Causes of Climate

Climate **forcing factors**: responsible for the climate fluctuations Earth has experienced throughout history

- External forcing factors: agents outside of Earth and in the atmosphere
- Internal forcing factors: originate on Earth

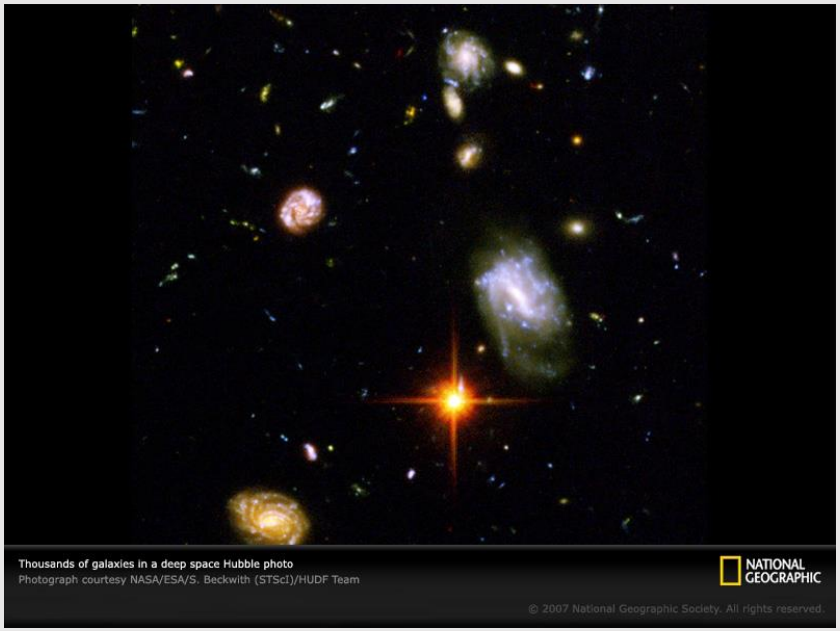
Climate Forcing Mechanisms

External

- Galactic variations
- Orbital variations
- Solar variations

Internal

- Orogeny
- Epeirogeny
- Volcanic activity
- Atmospheric composition



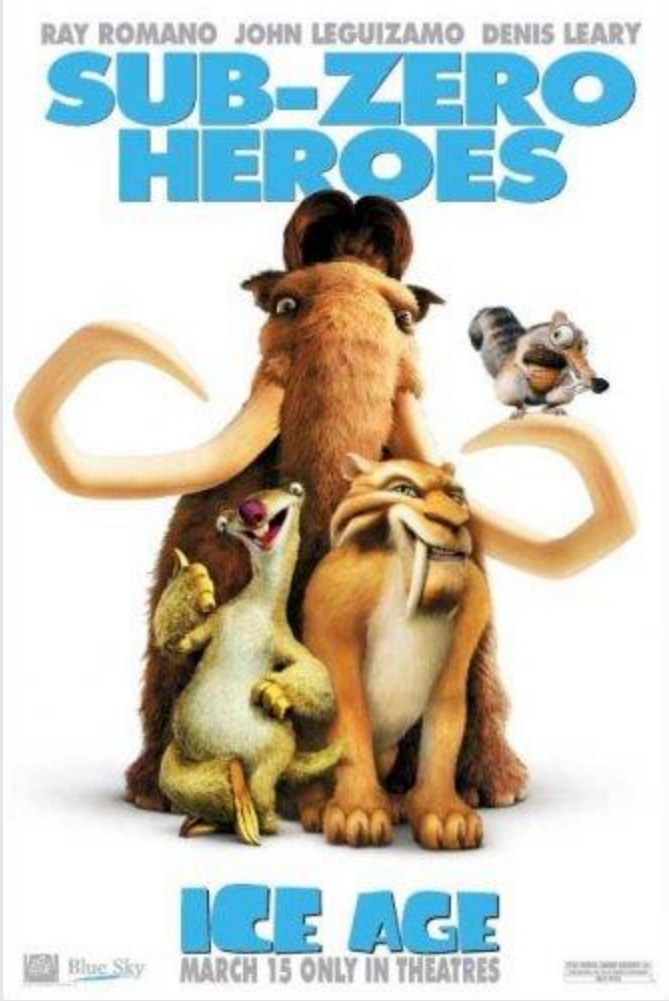
External Climate Forcing Mechanisms

- Galactic variations
- Orbital variations
  - Cosine law
  - Inverse square law
  - Obliquity
  - Eccentricity
  - Precession
  - Ice ages
- Solar variations
  - Sunspots

Ice Ages

Milankovitch Theory

- Serbian astrophysicist
- Ice ages occur in the N hemisphere when:
  - Axial tilt is small (small seasonal variations)
  - Eccentricity is large (large seasonal variations)
  - Earth is closest to the sun during N. Hemisphere winter (small variations)



Internal Climate Forcing Mechanisms

- Albedo
- Orogeny
- Epeirogeny
- Volcanism
- Atmospheric composition

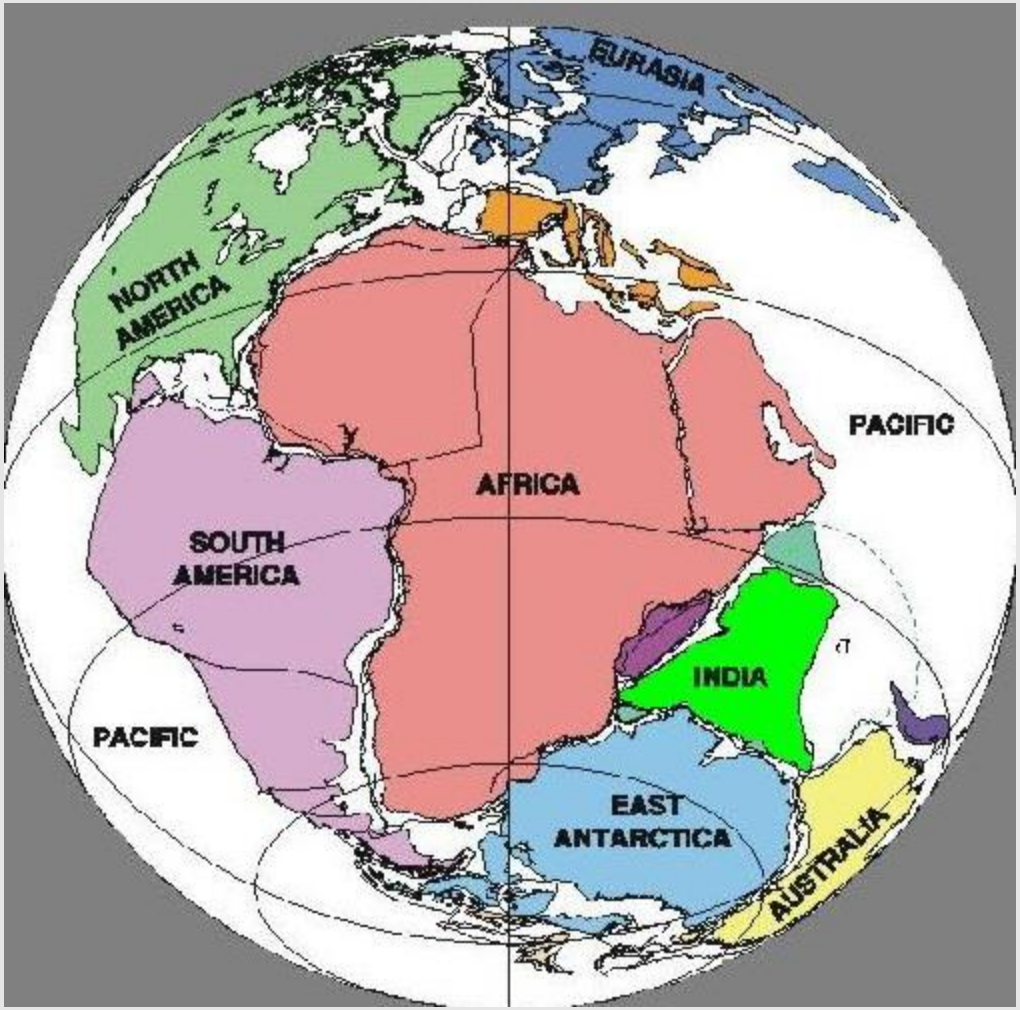
Albedo: percentage of solar energy reflected by Earth

As albedo increases, temperature decreases

– More energy being reflected back to space means less energy warming the earth

Orogeny: tectonic movements of Earth's crust or volcanic activities that form mountains

Epeirogeny: changes in global land mass distribution, driven by plate tectonics



Volcanism≠Vulcanism

Volcanism

Rapid effect on climate

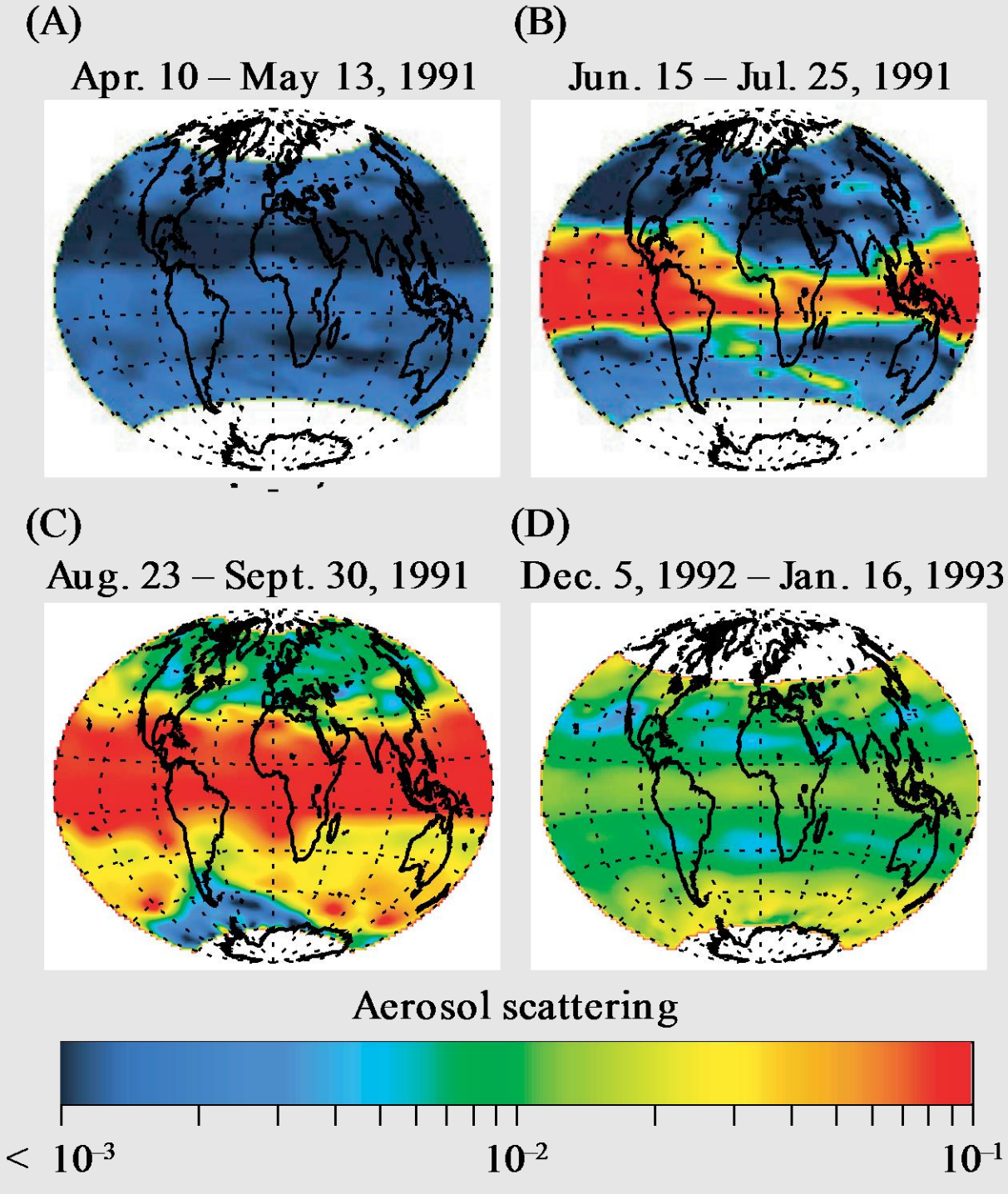
Release sulfur dioxide and fine particulates into upper atmosphere

- –Spreads globally
- –Reflects sunlight, lowers global temperature.

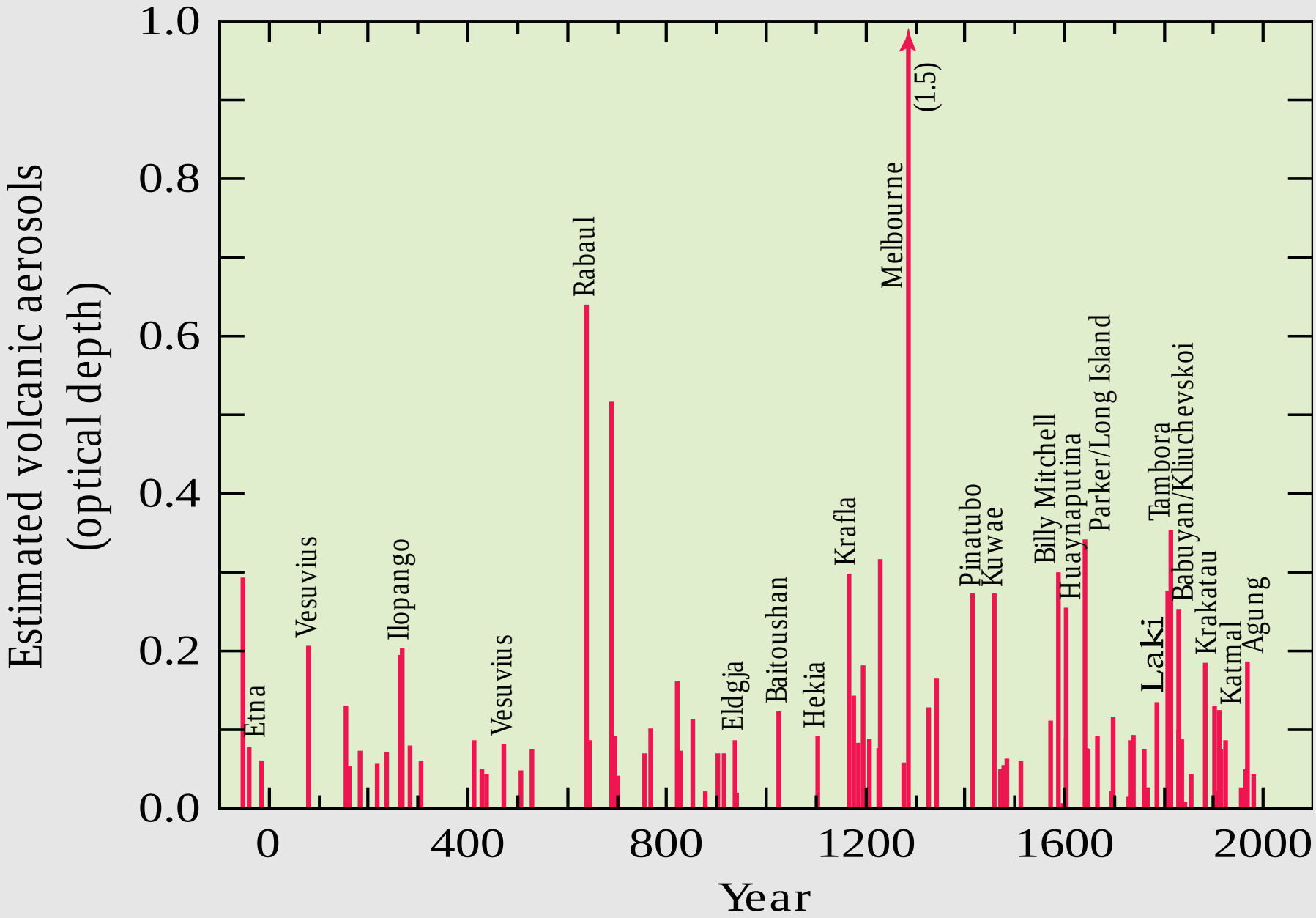
Mount Pinatubo (1991)

Caused global cooling of 0.1 – 0.5°C

Decreased temperatures persisted 1 – 3 years


(A)
Apr. 10 – May 13, 1991
(B)
Jun. 15 – Jul. 25, 1991
(C)
Aug. 23 – Sept. 30, 1991
(D)
Dec. 5, 1992 – Jan. 16, 1993
Aerosol scattering
< 10⁻³
10⁻²
10⁻¹

Volcanic activity is regular but not predictable



Internal Climate Forcing Mechanisms

Albedo

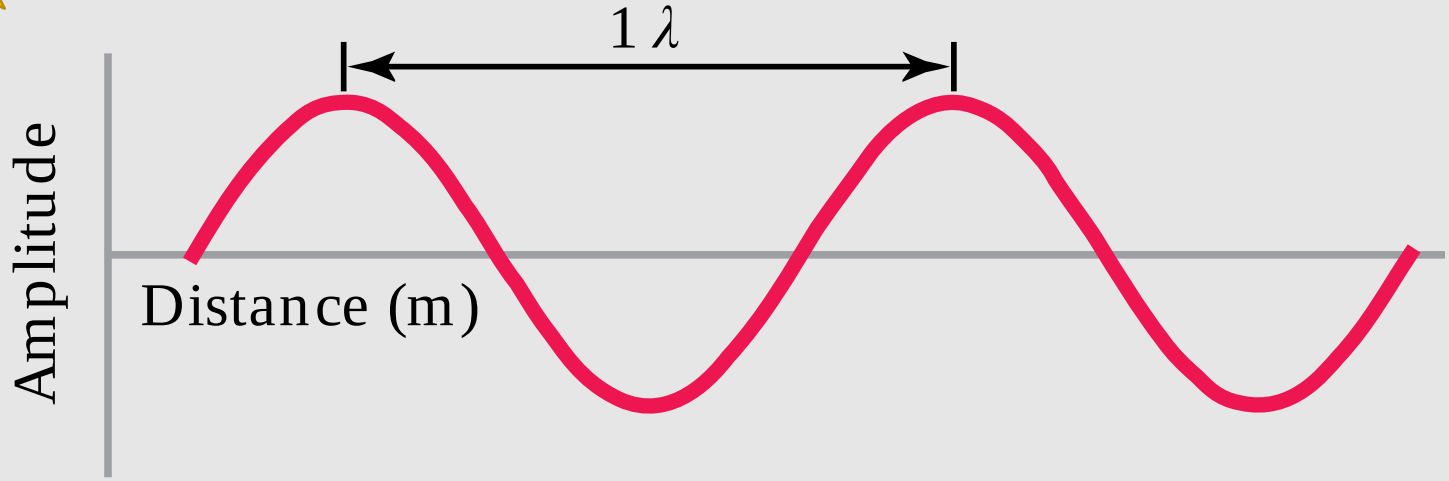
Orogeny

Epeirogeny

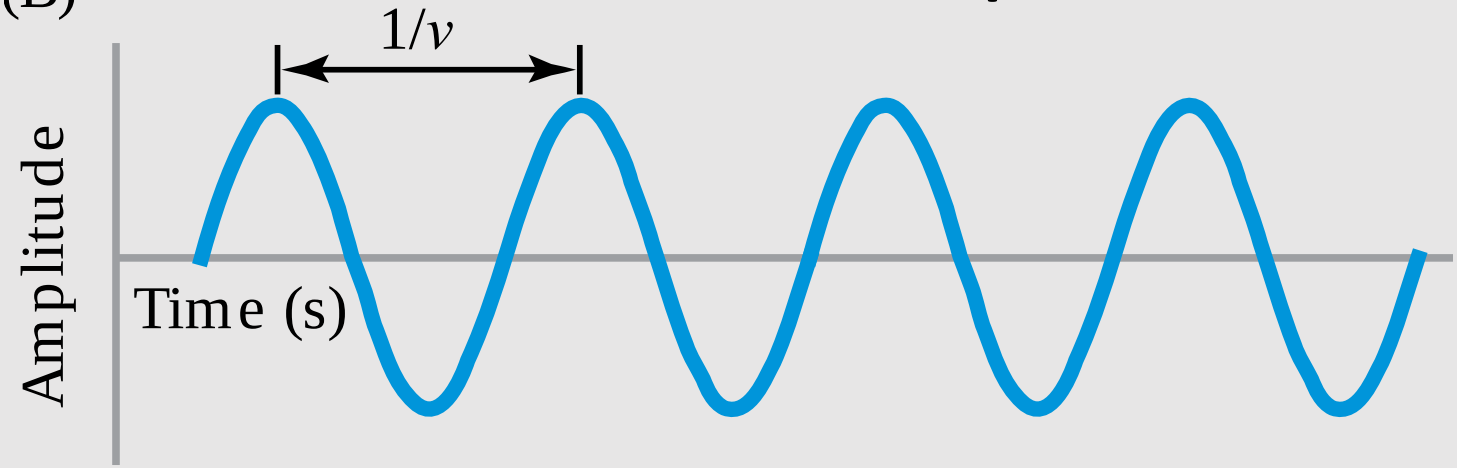
Volcanism

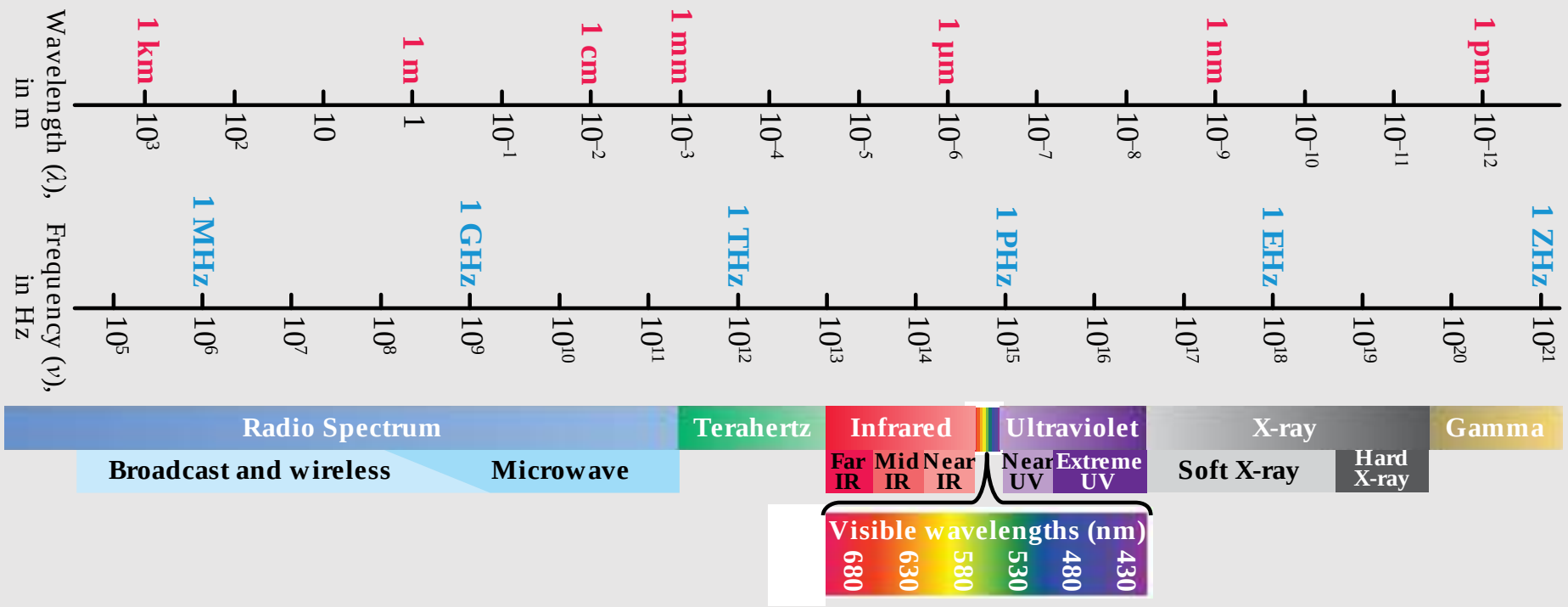
Atmospheric composition

(A) **WAVELENGTH: distance between successive peaks**



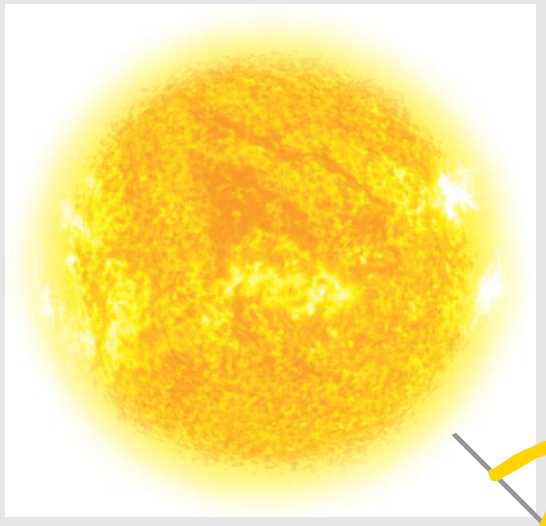
(B) **FREQUENCY: # of successive peaks/unit time**

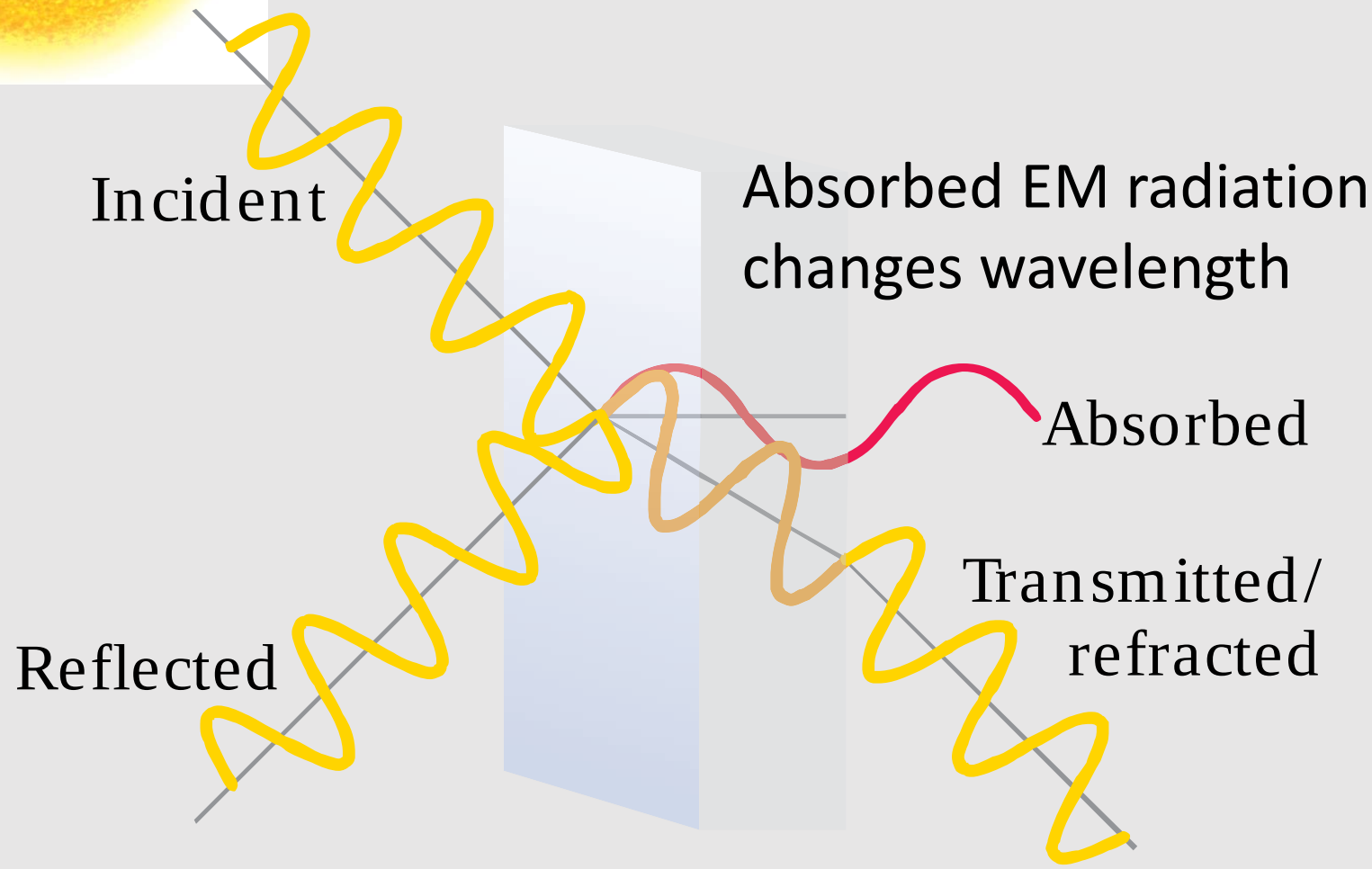


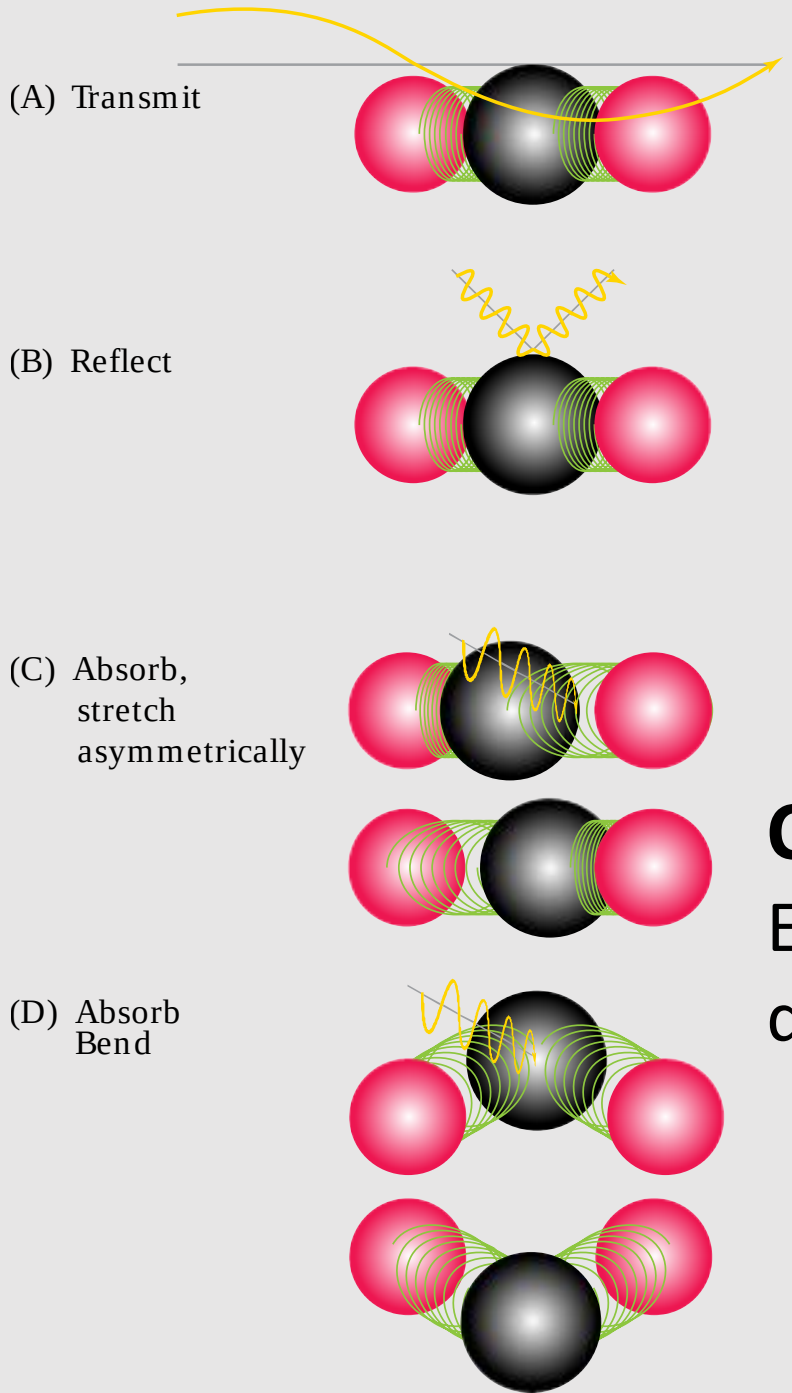


long wavelengths
(slow frequencies)
LESS ENERGY

short wavelengths
(high frequencies)
MORE ENERGY




Incident
Absorbed EM radiation changes wavelength
Absorbed
Transmitted/ refracted
Reflected



- Molecules that absorb EM radiation move
- They get WARM
- Re-radiate EM radiation at a longer wavelength

Conservation of Energy Law

Energy is neither created nor destroyed. It only changes form

Earth's Atmosphere

Noble Gases

Nitrogen

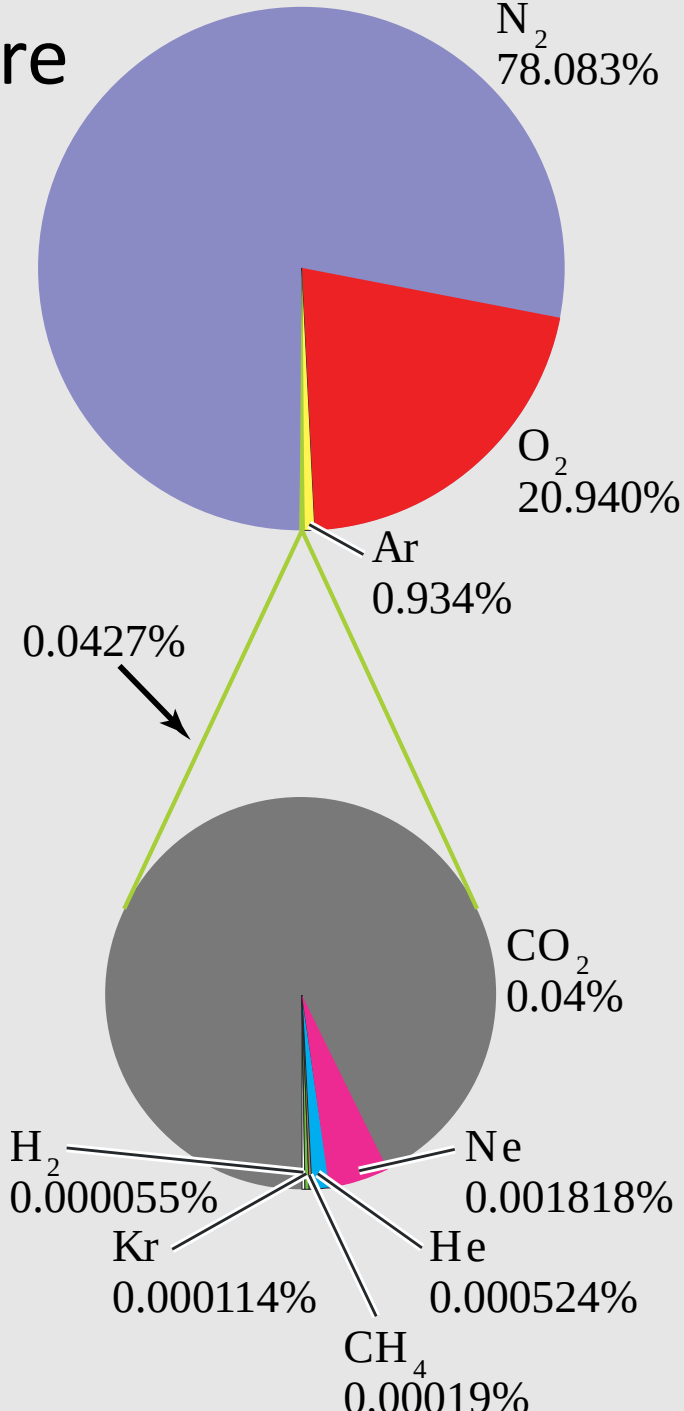
Argon

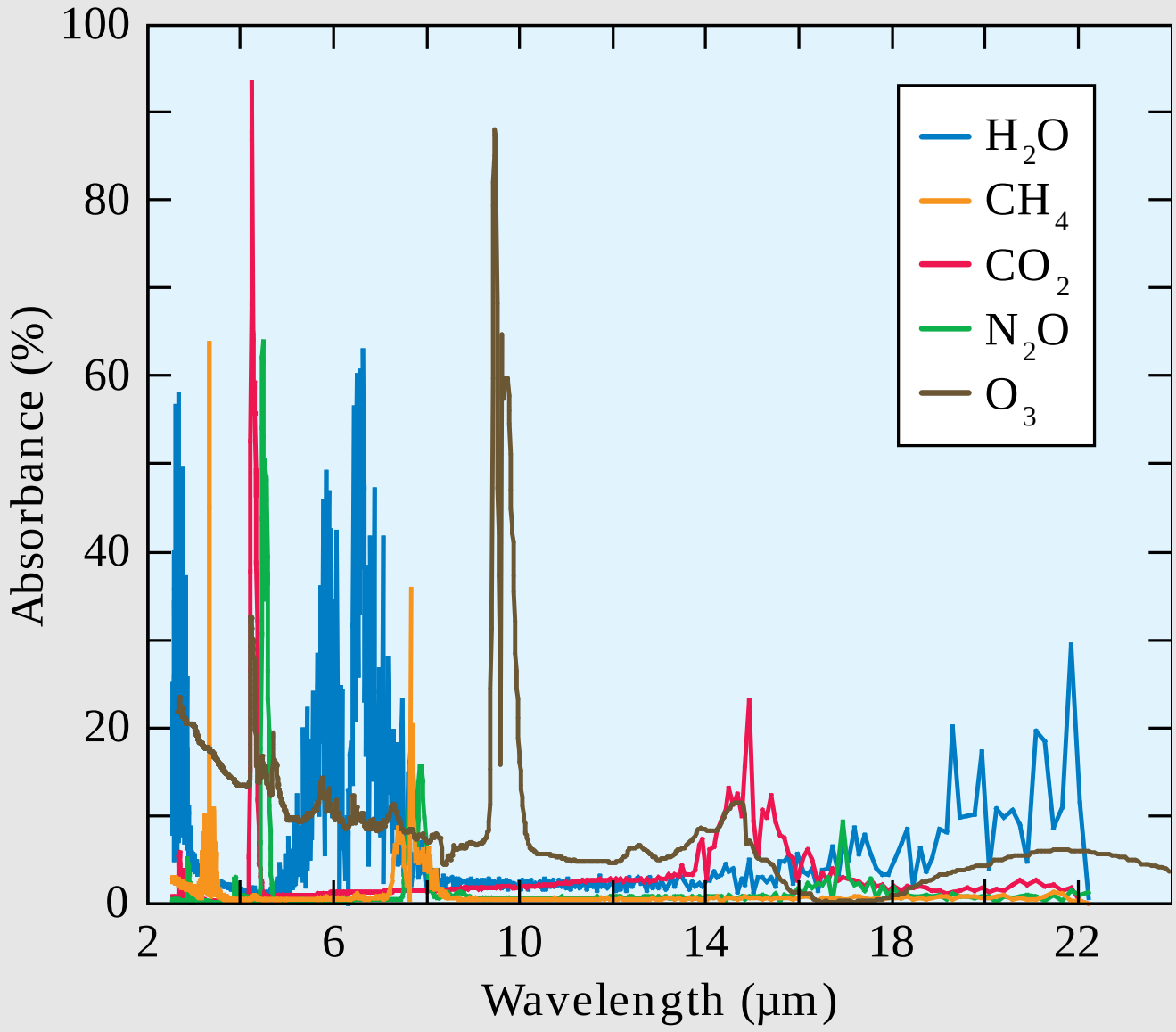
Neon

Helium

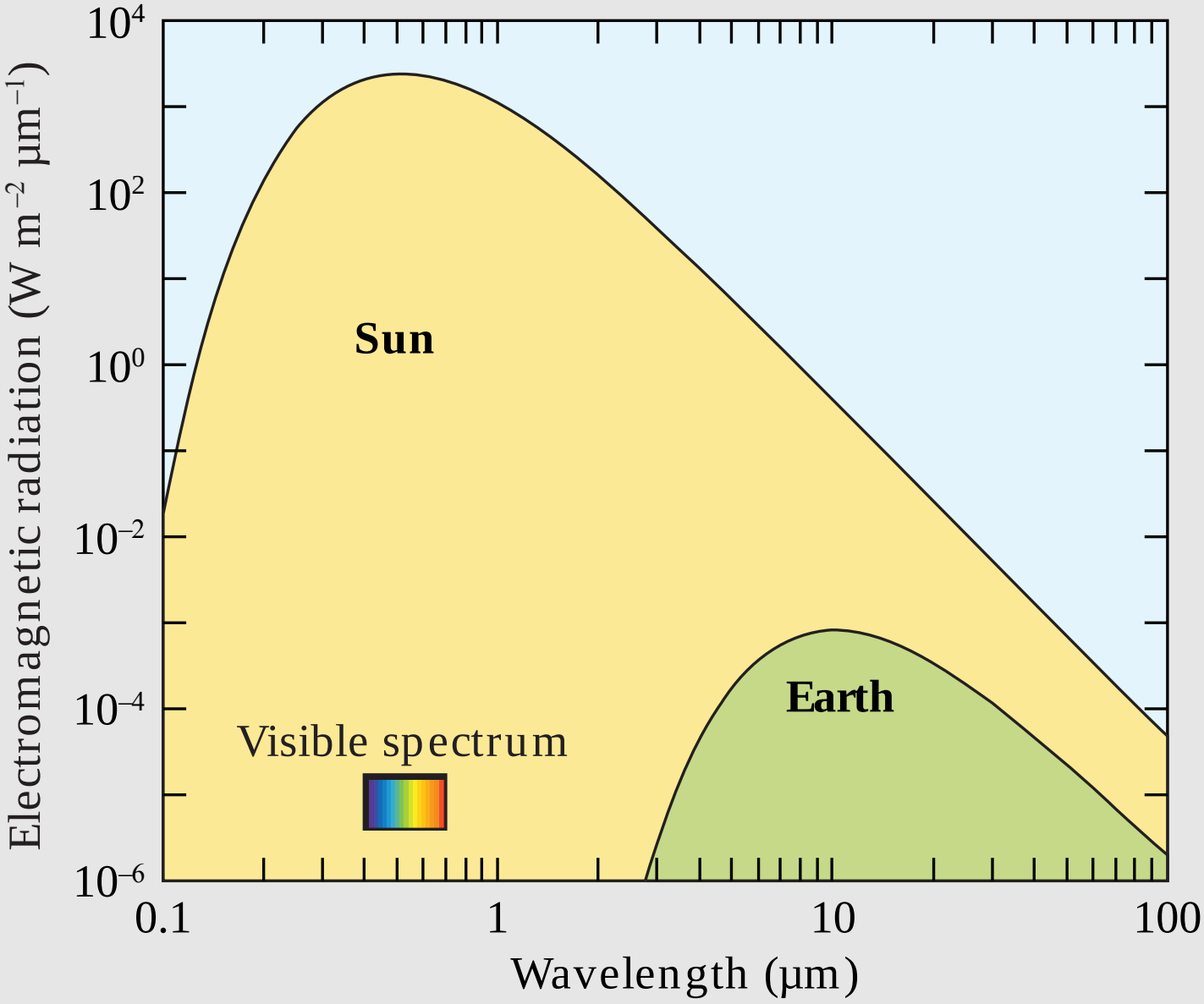
Krypton

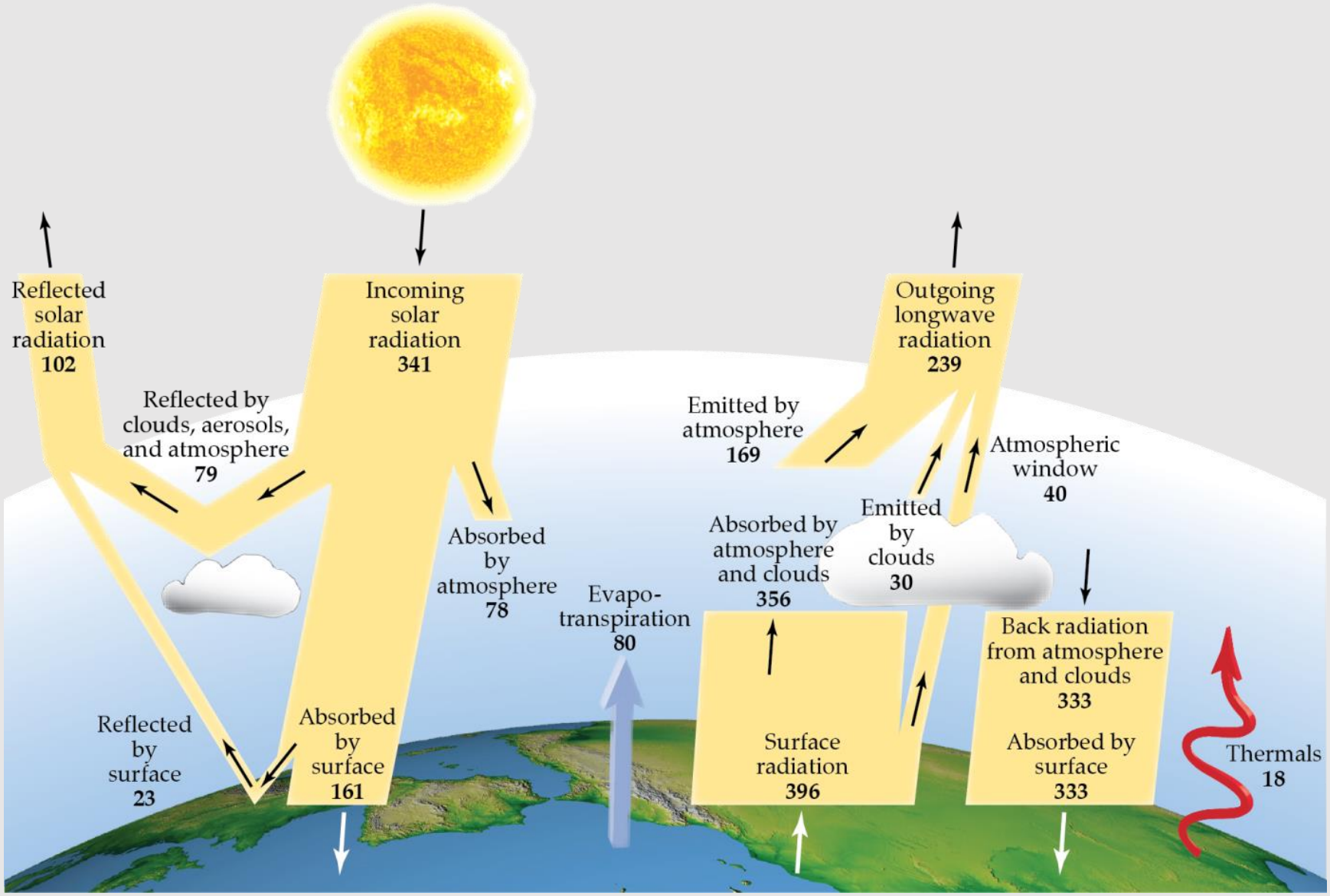
Xenon



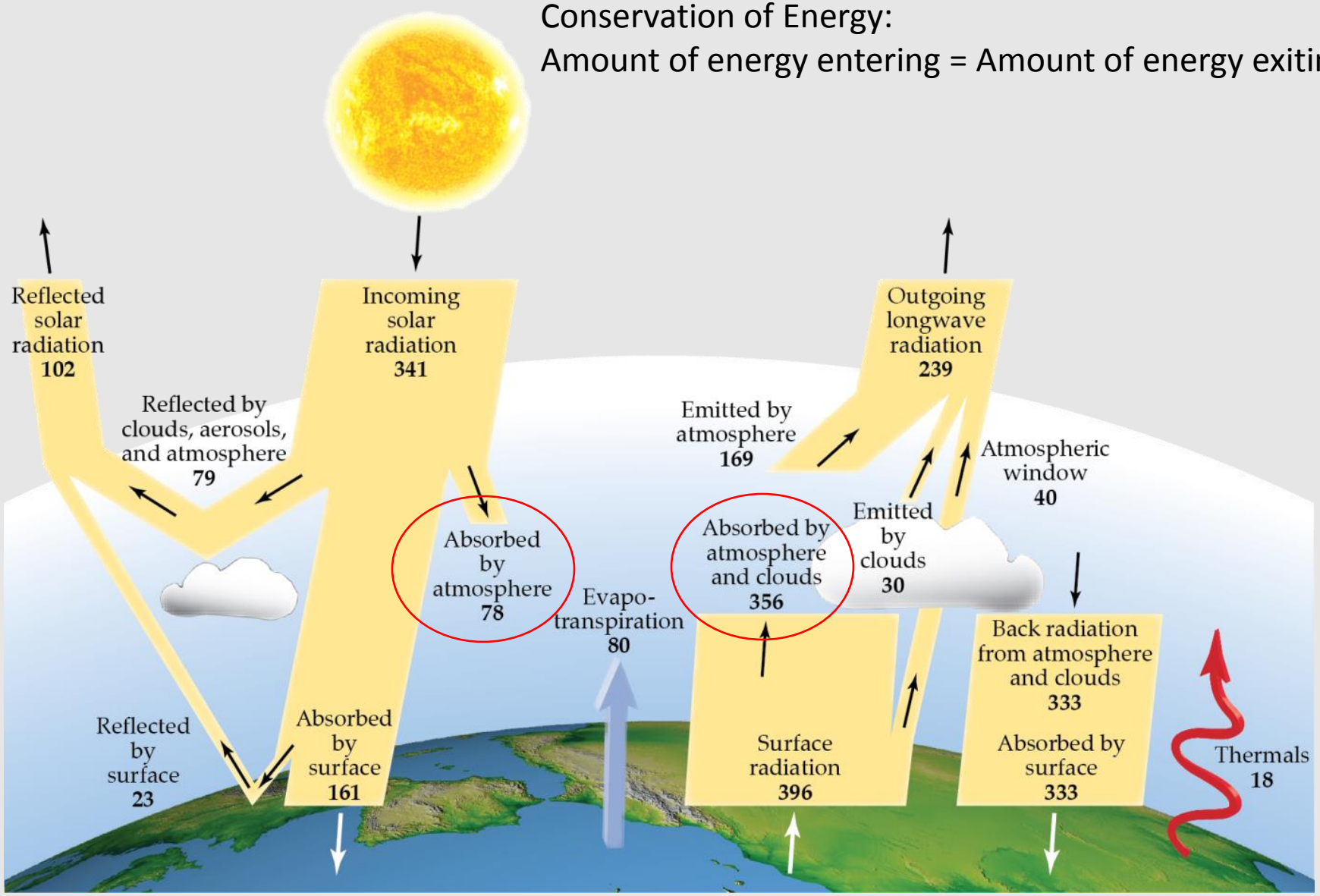


Each gas only absorbs EM radiation at certain wavelengths


Electromagnetic radiation (W m⁻² μm⁻¹)
10⁴
10²
10⁰
10⁻²
10⁻⁴
10⁻⁶
Sun
Earth
Visible spectrum
0.1
1
10
100
Wavelength (μm)


Reflected solar radiation 102
Incoming solar radiation 341
Outgoing longwave radiation 239
Reflected by clouds, aerosols, and atmosphere 79
Emitted by atmosphere 169
Atmospheric window 40
Absorbed by atmosphere 78
Absorbed by atmosphere and clouds 356
Emitted by clouds 30
Evapo-transpiration 80
Back radiation from atmosphere and clouds 333
Reflected by surface 23
Absorbed by surface 161
Surface radiation 396
Absorbed by surface 333
Thermals 18

Conservation of Energy:
Amount of energy entering = Amount of energy exiting

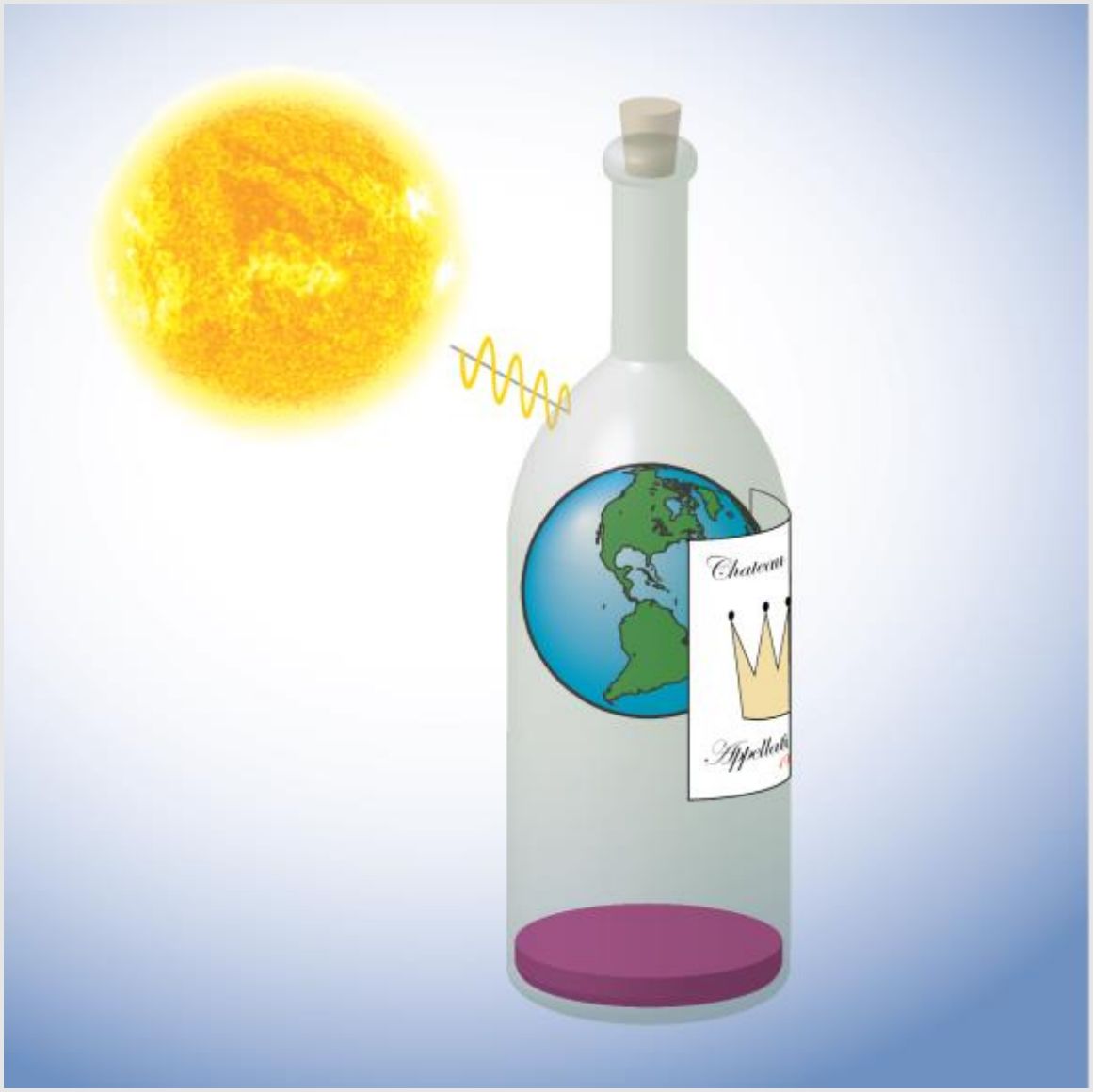


Greenhouse Effect

The amount of energy entering = amount of energy exiting

It just changes form

When absorbed, generates heat (molecular motion) and changes to longer wavelength



Most of energy enters as visible light (short wavelength)

Most escapes as infrared (long wavelength) that is no longer absorbed

Greenhouse Gases

Gas	Common name	Concentration (ppb)[a]	Lifetime (years)[b]	Warming potential[c]
CO_2	Carbon dioxide	391,000	52.4	1
CH_4	Methane	1800	12.4	28
N_2O	Nitrous oxide	324	121.0	265
CO	Carbon monoxide	130	0.2	2
CCl_3F	CFC-11	0.24	45.0	4660
CF_2Cl_2	CFC-12	0.53	100.0	10,200
$CHClF_2$	HCFC-22	0.21	11.9	1760
CCl_4	Carbon tetrachloride	0.086	26.0	1730
CCl_2FCClF_2	CFC-113	0.074	85.0	5820
CH_3Cl	Methyl chloride	0.55	1.0	12
CH_3CCl_3	Methyl chloroform	0.0063	5.0	160
CH_2Cl_2	Dichloromethane	0.04	0.4	9
CH_3CClF_2	HCFC-142b	0.021	17.2	1980
$CHCl_3$	Chloroform	0.01	0.4	16
SF_6	Sulfur hexafluoride	0.0073	3200	23,500

https://www.youtube.com/watch?v=aCnf46boC3I

Clouds

Reflect incoming solar radiation (high albedo)

- Cools the planet

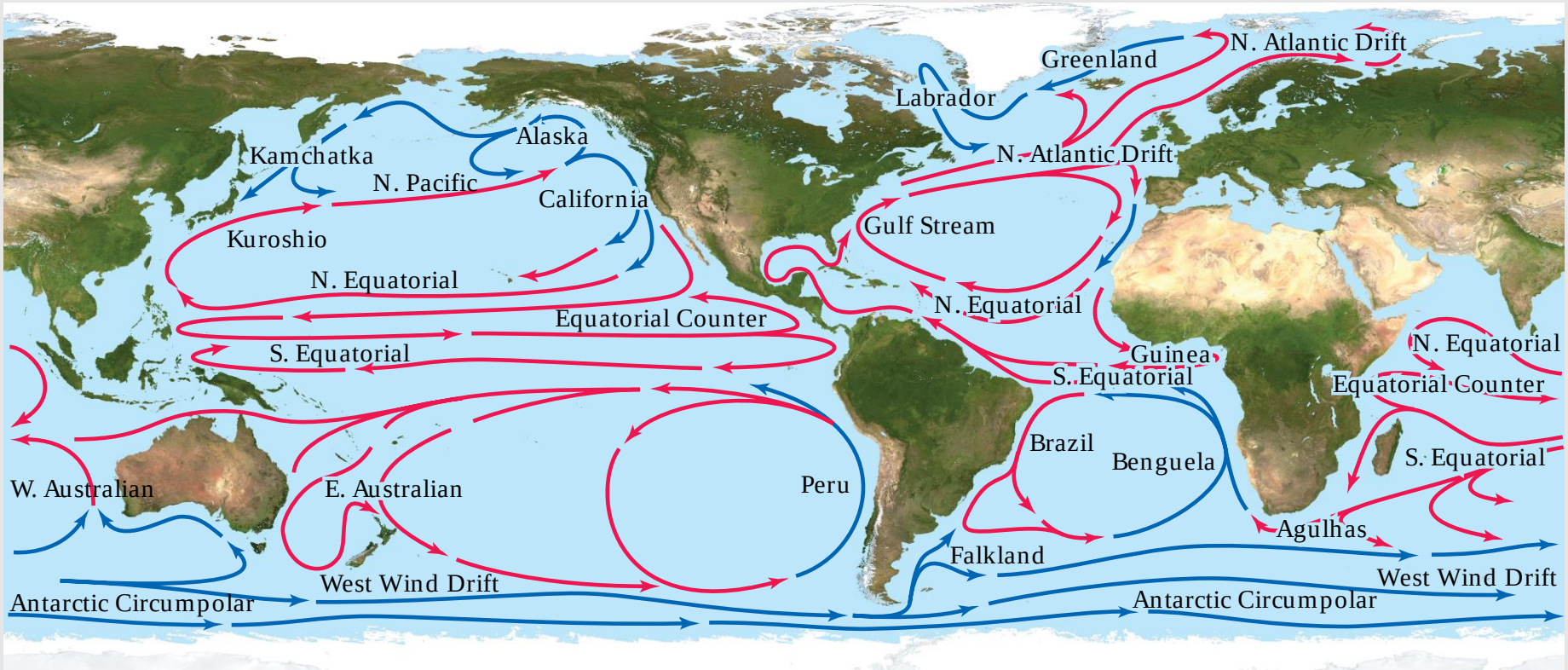
Absorb radiation from Earth's surface and re-radiate (like a GHG)

- Warms the planet

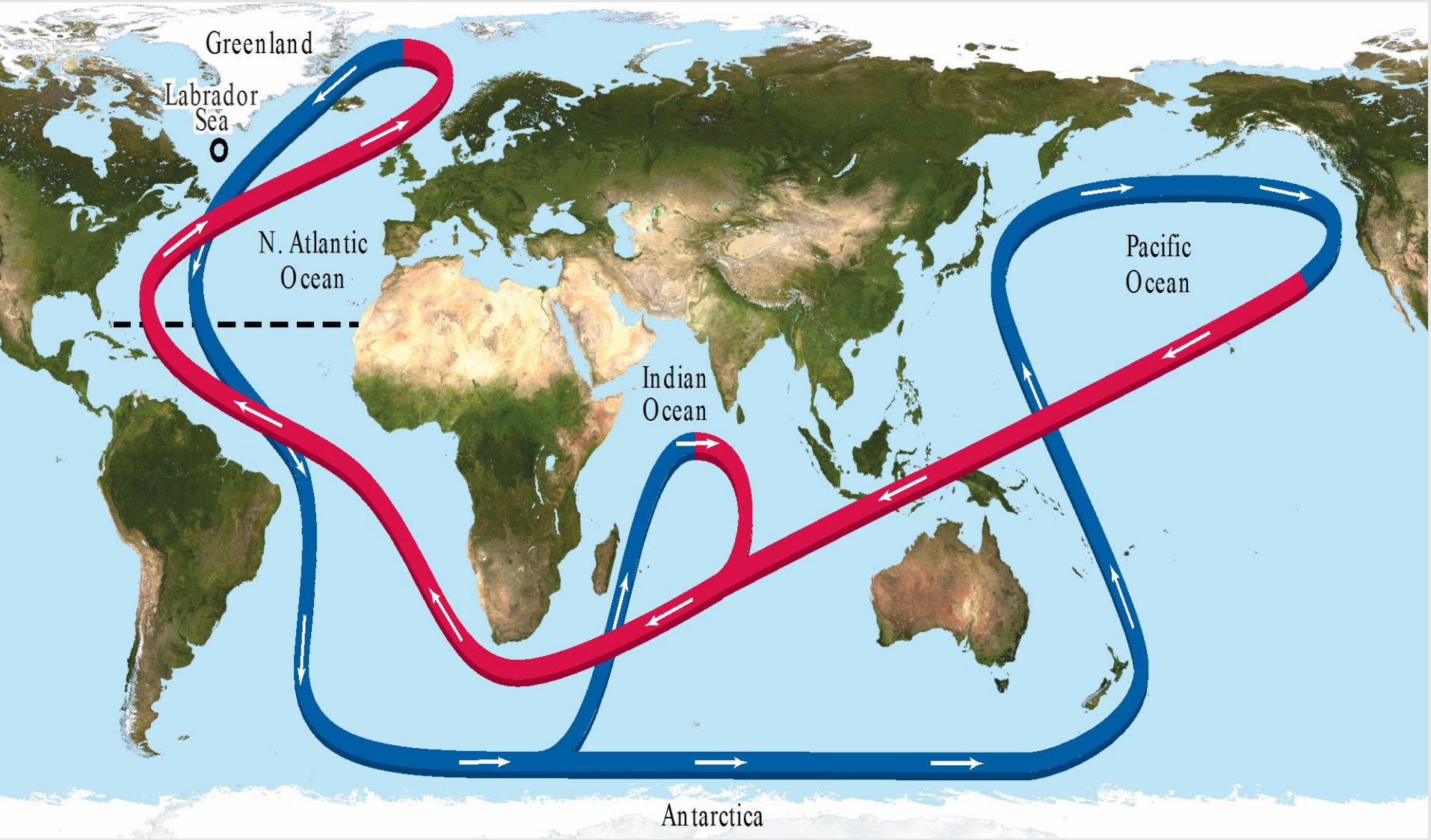
NET EFFECT = COOLING

Ocean currents

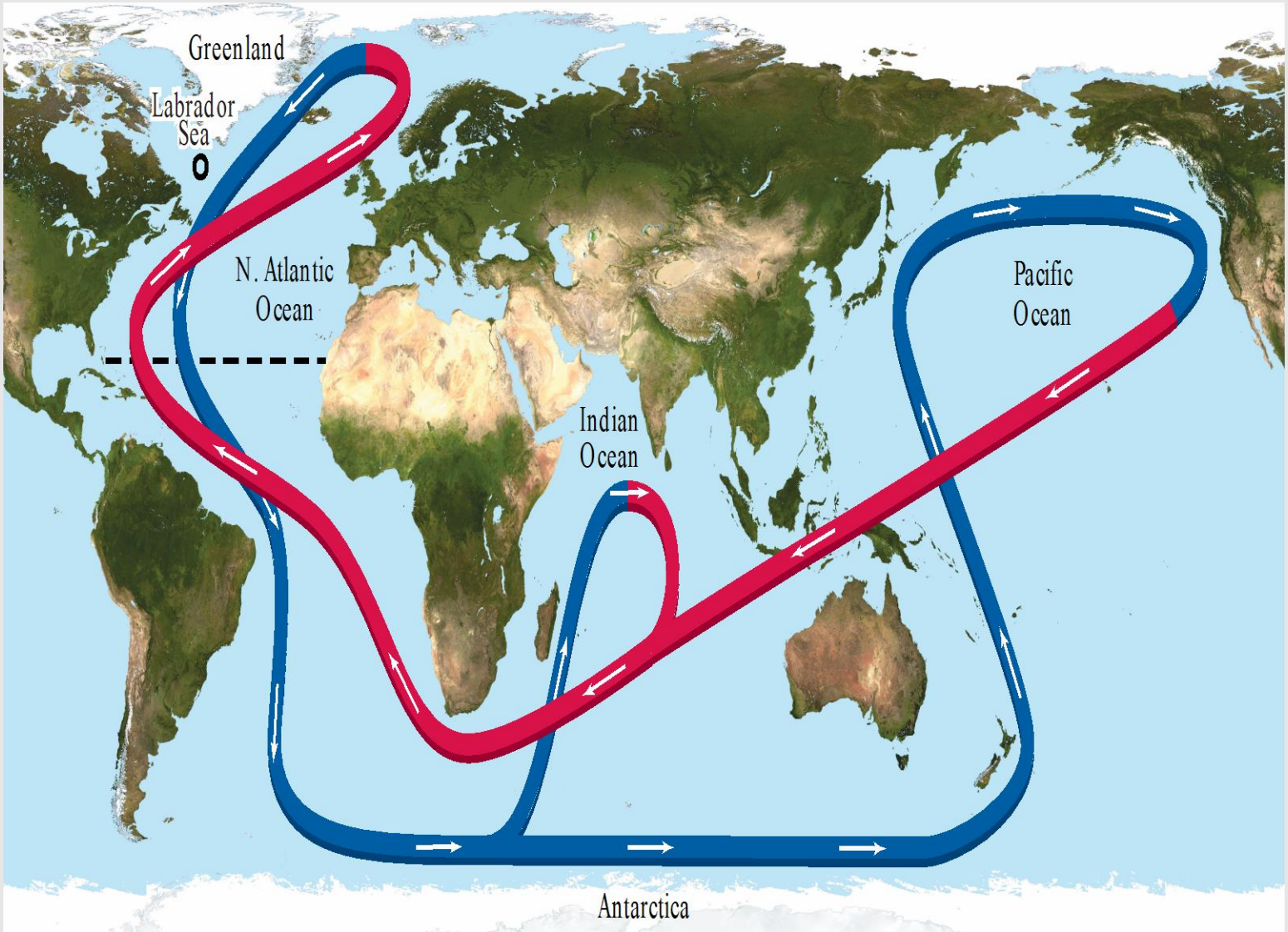
- Differences in solar energy received by the equator and the poles
- Topography of the ocean floor and coastal landmasses
- Changes in seawater density
- Rotation of Earth around its axis
- Atmospheric winds



Ocean Conveyer Belt



Ocean Conveyer Belt



Cold, dense water sinks at the poles

Warm water rises at the equator

Warming at poles

- Decreases albedo (more warming)
- Increases ice melt
- Decreases salinity (more fresh water melting into ocean)

Critical desalinization point???

https://www.youtube.com/watch?v=O2bf5NmeWkM
http://www.youtube.com/watch?v=js183HfE91Q